ESC201T : Introduction to Electronics

Lecture 22: Diode Circuits

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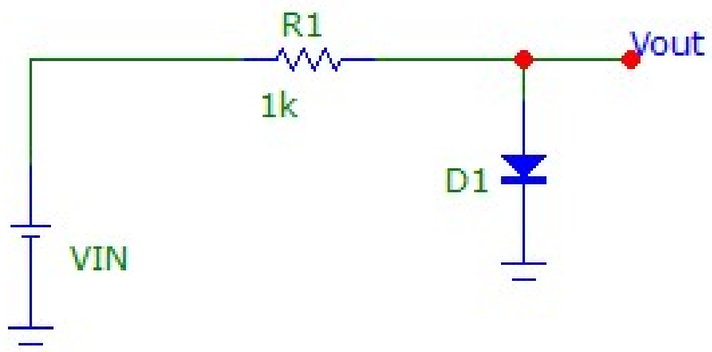
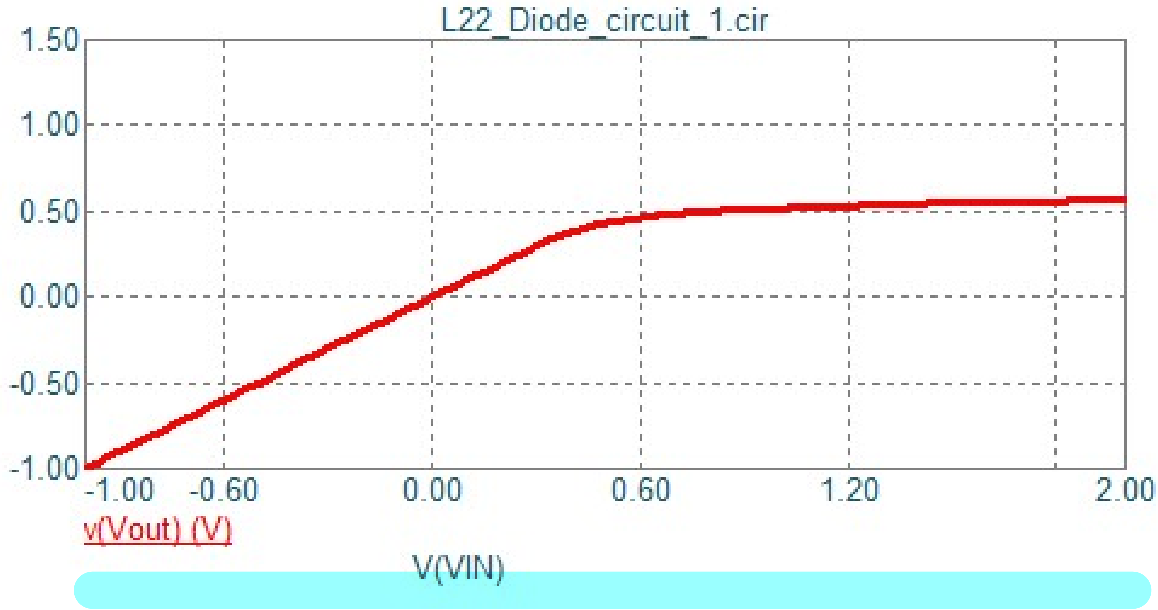

R1
1k
Vout
D1
VIN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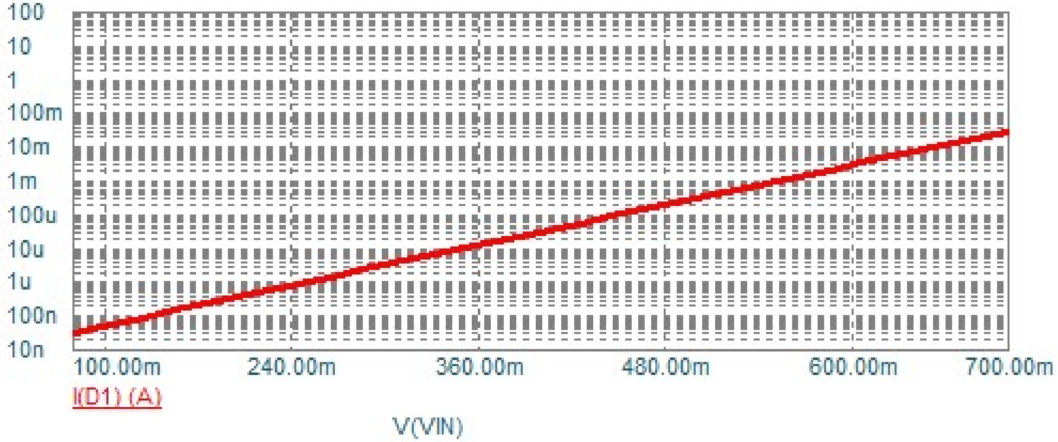
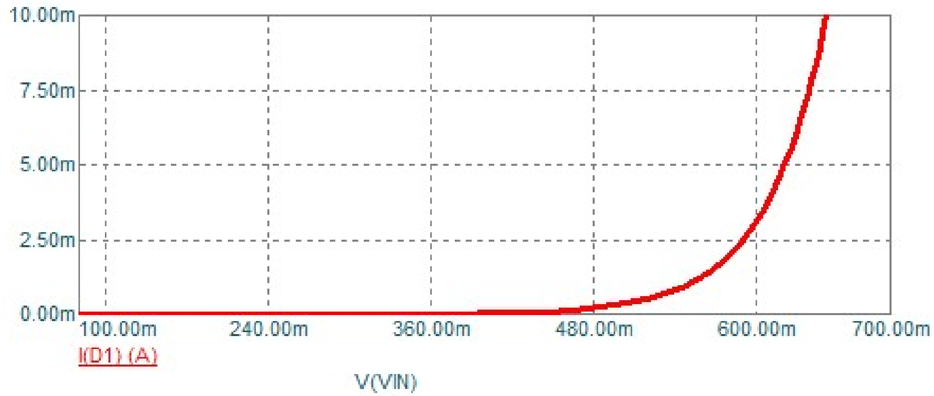
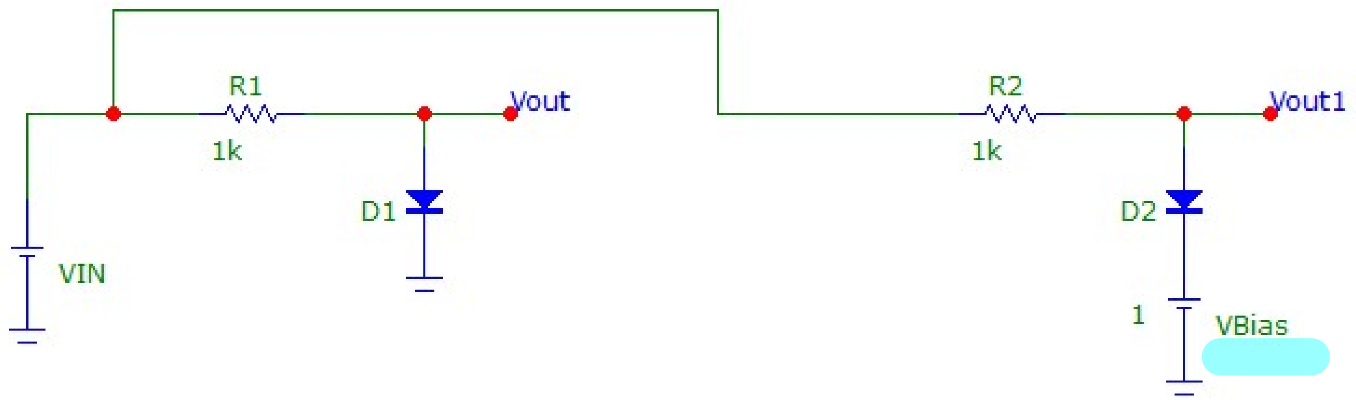
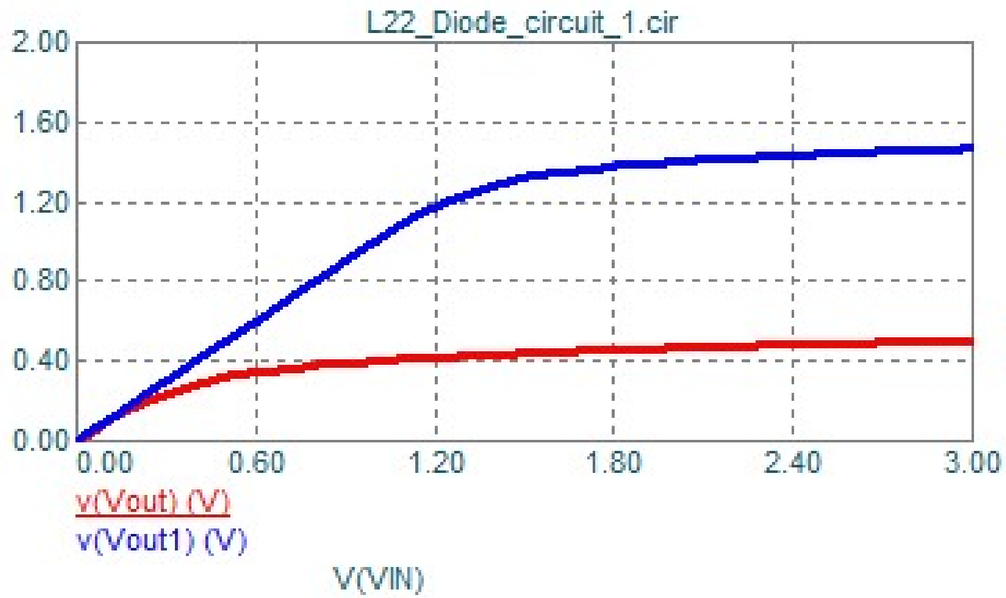
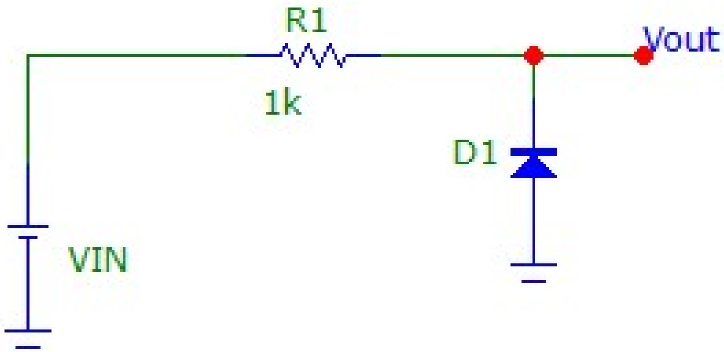
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.00
-0.60
0.00
0.60
1.20
2.00
v(Vout) (V)
V(VIN)

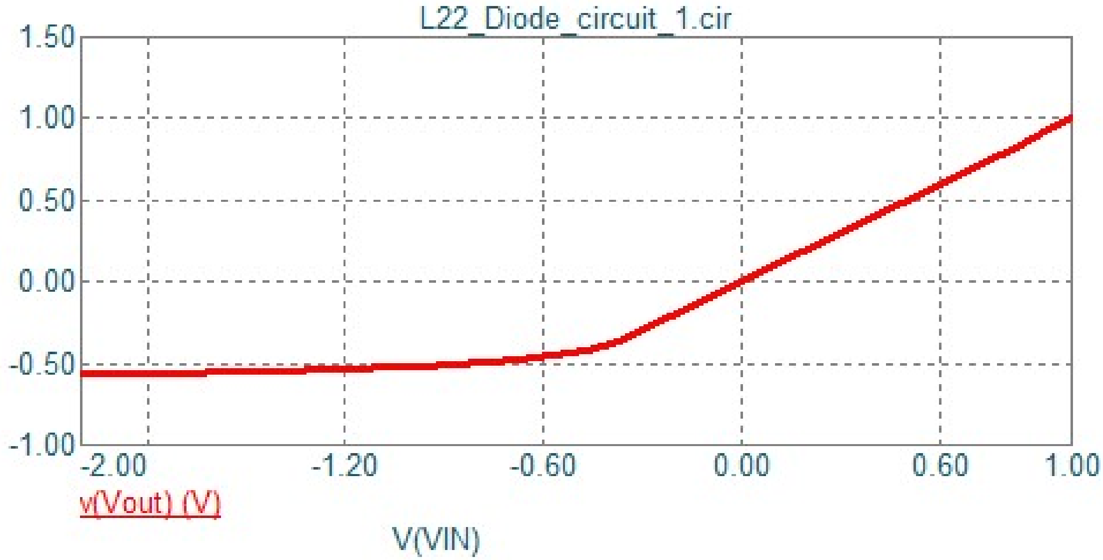

100
10
1
100m
10m
1m
100u
10u
1u
100n
10n
100.00m
240.00m
360.00m
480.00m
600.00m
700.00m
I(D1) (A)
V(VIN)


10.00m
7.50m
5.00m
2.50m
0.00m
100.00m
240.00m
360.00m
480.00m
600.00m
700.00m
I(D1) (A)
V(VIN)

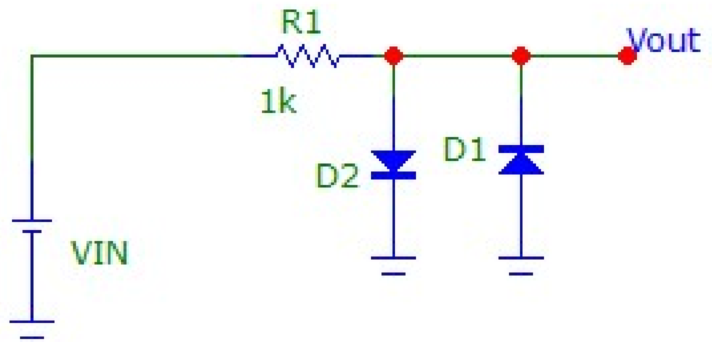

R1
1k
Vout
D1
VIN
R2
1k
Vout1
D2
1
VBias

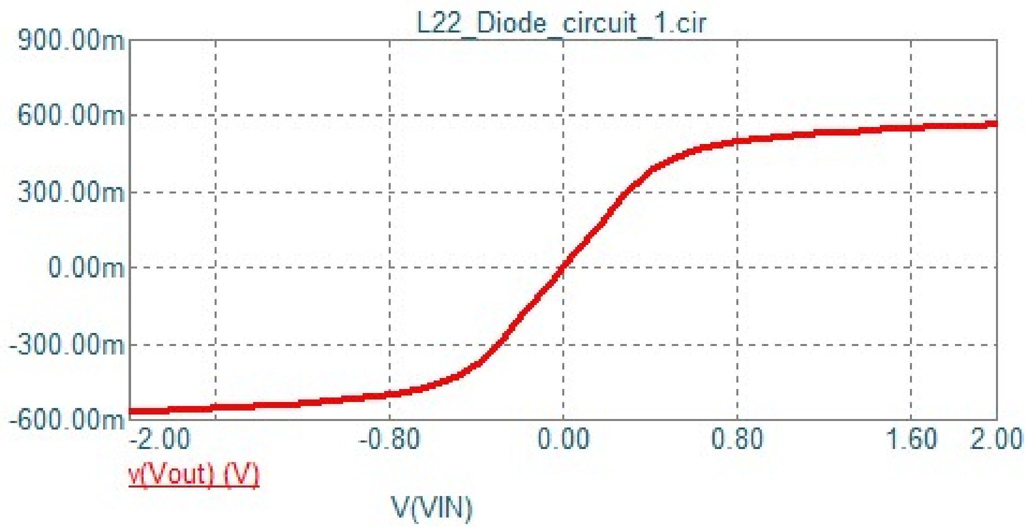

L22_Diode_circuit_1.cir
2.00
1.60
1.20
0.80
0.40
0.00
0.00
0.60
1.20
1.80
2.40
3.00
v(Vout) (V)
v(Vout1) (V)
V(VIN)

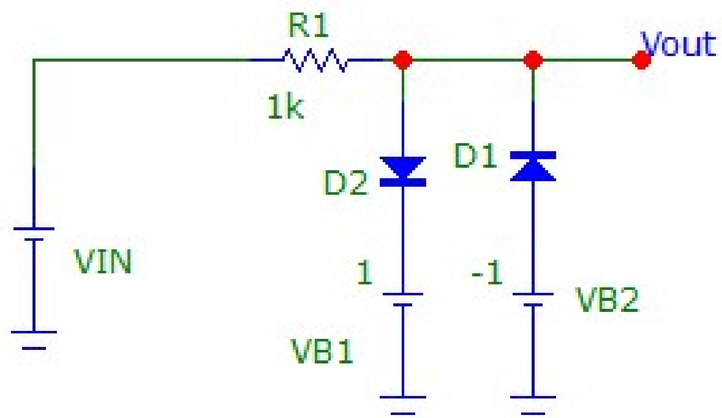

R1
1k
Vout
D1
VIN

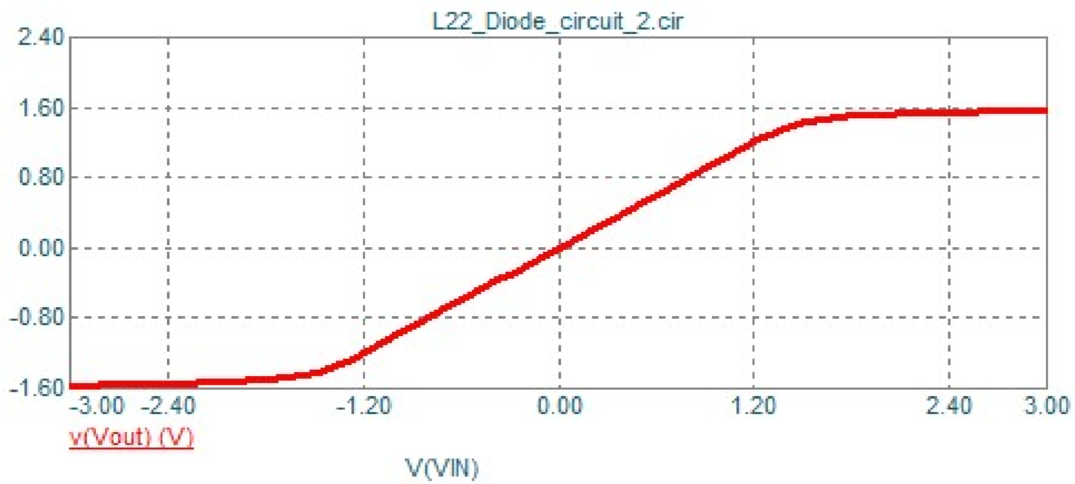

L22_Diode_circuit_1.cir
1.50
1.00
0.50
0.00
-0.50
-1.00
-2.00
-1.20
-0.60
0.00
0.60
1.00
v(Vout) (V)
V(VIN)

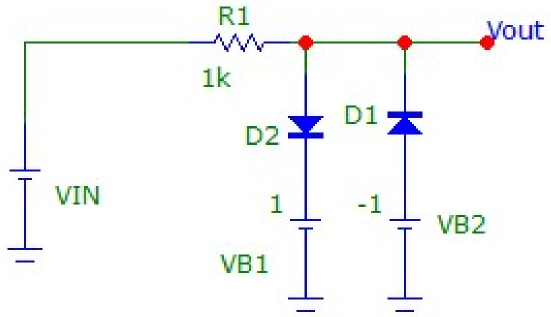
Clipper Circuit

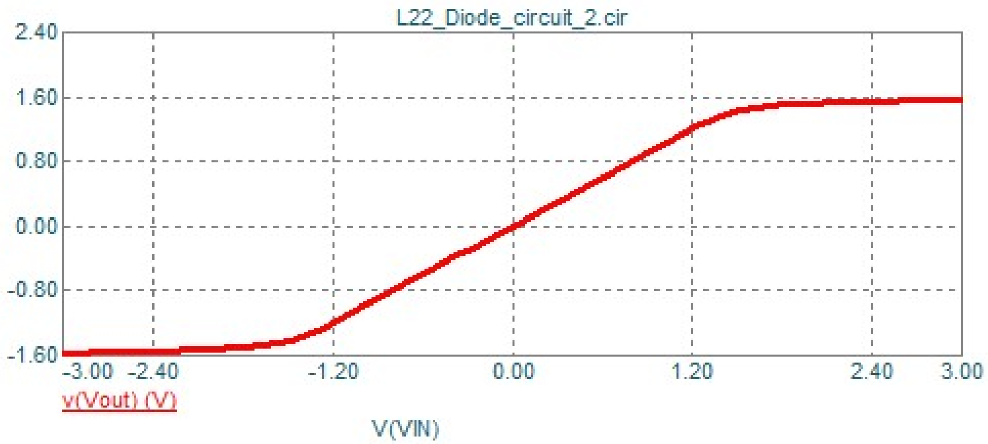


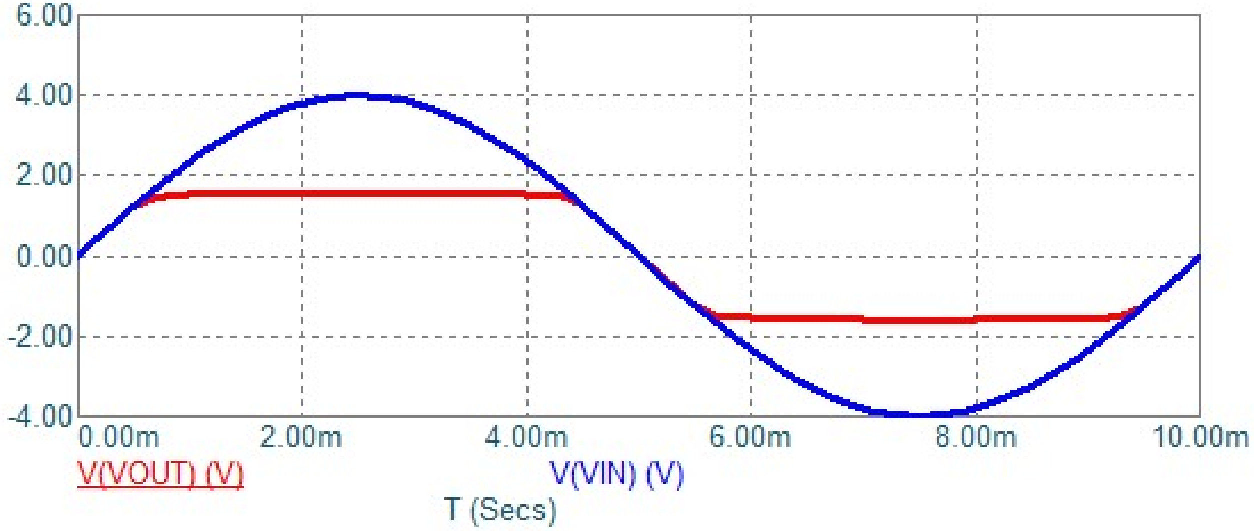






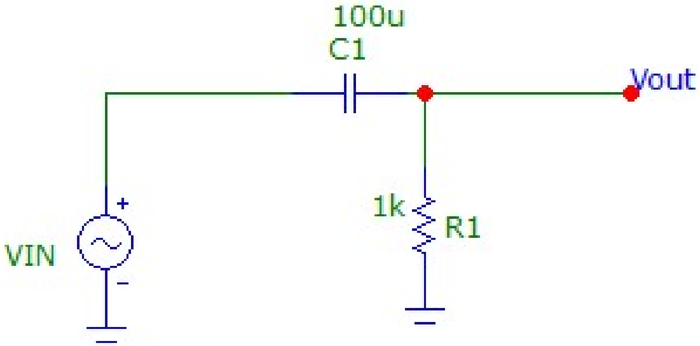

R1
1k
Vout
D2
D1
VIN
1
-1
VB2
VB1

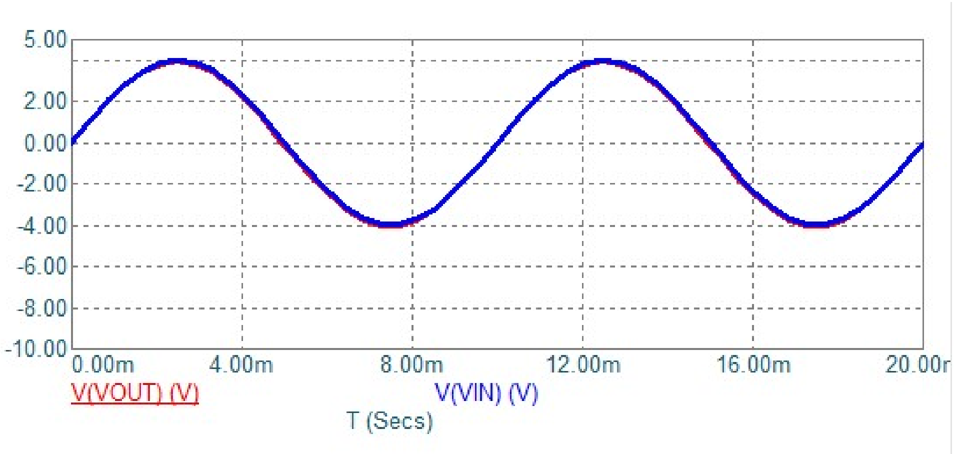

L22_Diode_circuit_2.cir
2.40
1.60
0.80
0.00
-0.80
-1.60
-3.00
-2.40
-1.20
0.00
1.20
2.40
3.00
v(Vout) (V)
V(VIN)


6.00
4.00
2.00
0.00
-2.00
-4.00
0.00m
2.00m
4.00m
6.00m
8.00m
10.00m
V(VOUT) (V)
V(VIN) (V)
T (Secs)

Negative Clamper

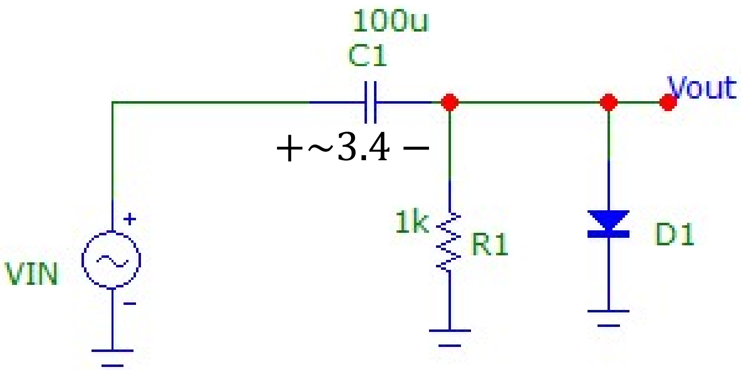
$\tau = 0.1s$

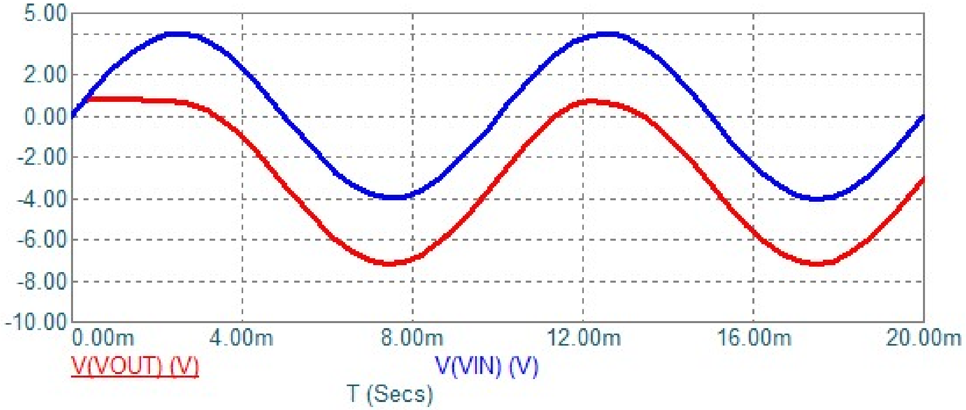




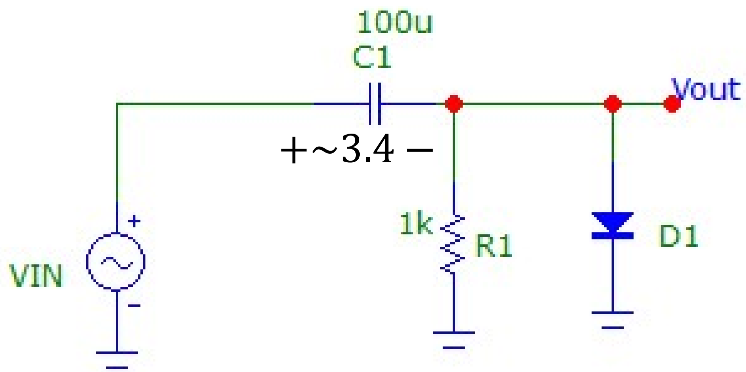
$4V sin(\omega t)$

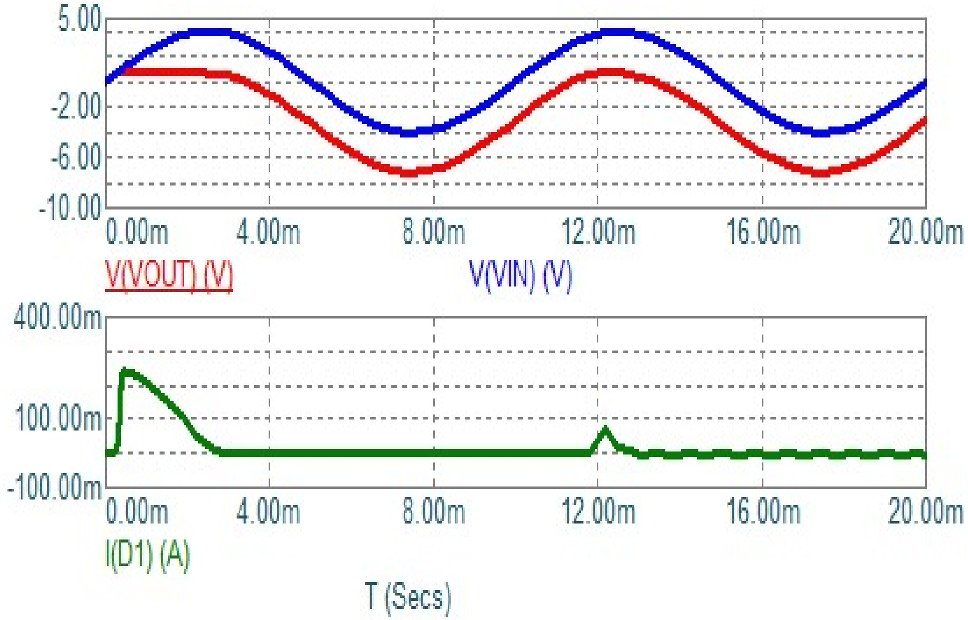
$f = 100Hz$





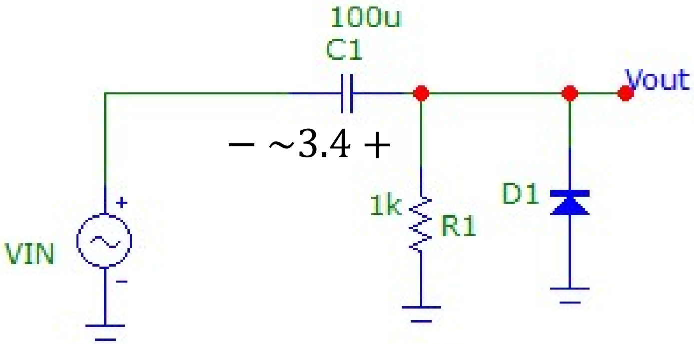
$$V_{IN} - V_{OUT} \sim 3.4 \Rightarrow V_{OUT} = V_{IN} - 3.4$$


100u
C1
Vout
+~3.4 −
1k
R1
D1
VIN


5.00
-2.00
-6.00
-10.00
0.00m
4.00m
8.00m
12.00m
16.00m
20.00m
V(VOUT) (V)
V(VIN) (V)
400.00m
100.00m
-100.00m
0.00m
4.00m
8.00m
12.00m
16.00m
20.00m
I(D1) (A)
T (Secs)

Positive Clamper

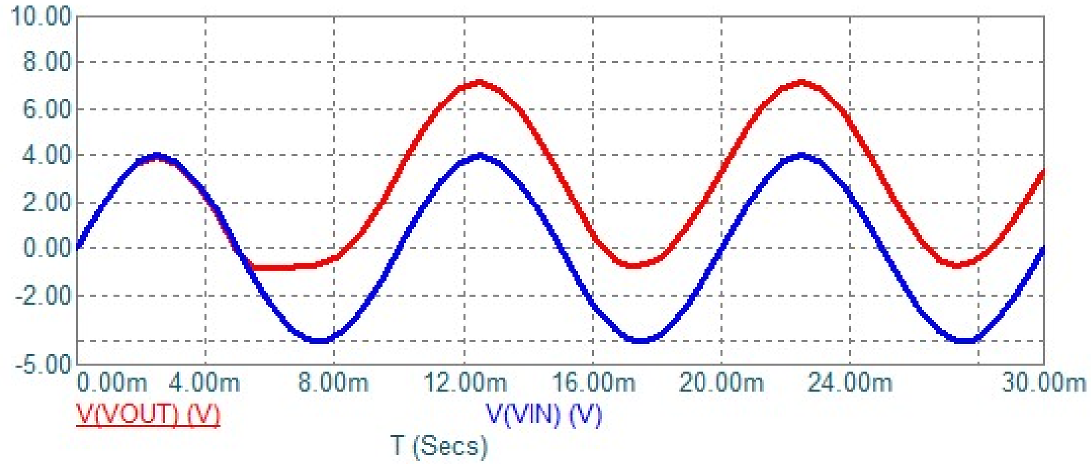
$$\tau = 0.1s$$



$$- \sim 3.4 +$$

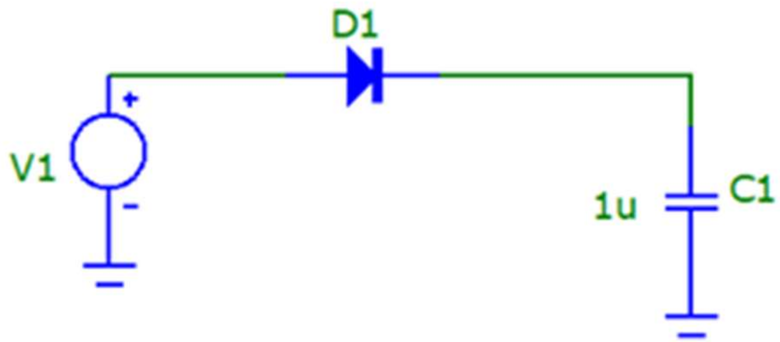
$4Vsin(\omega t)$

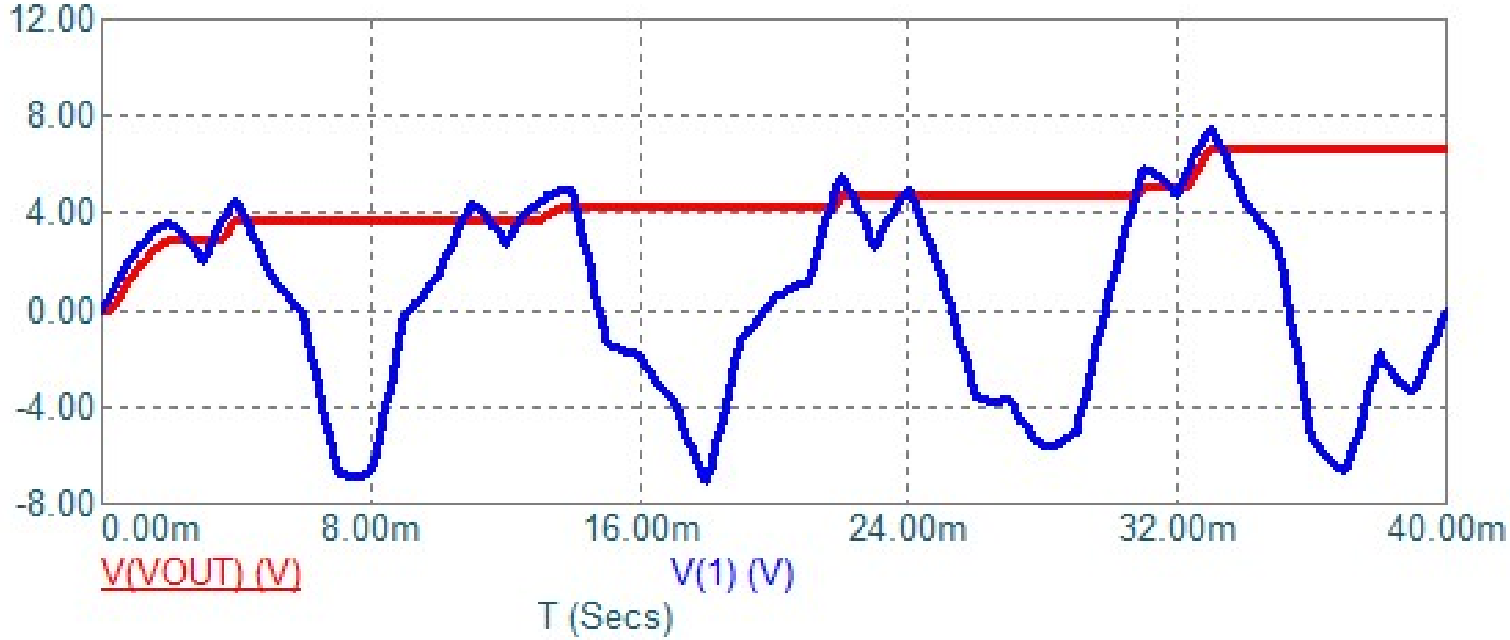
$f = 100Hz$



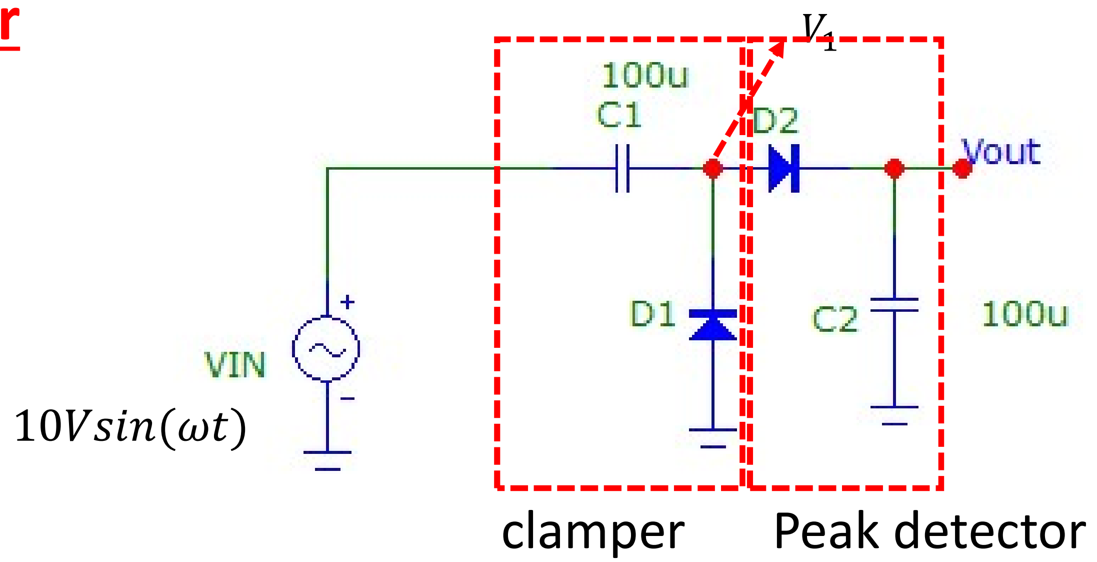
$$V_{IN} - V_{OUT} \sim -3.4 \Rightarrow V_{OUT} = V_{IN} + 3.4$$

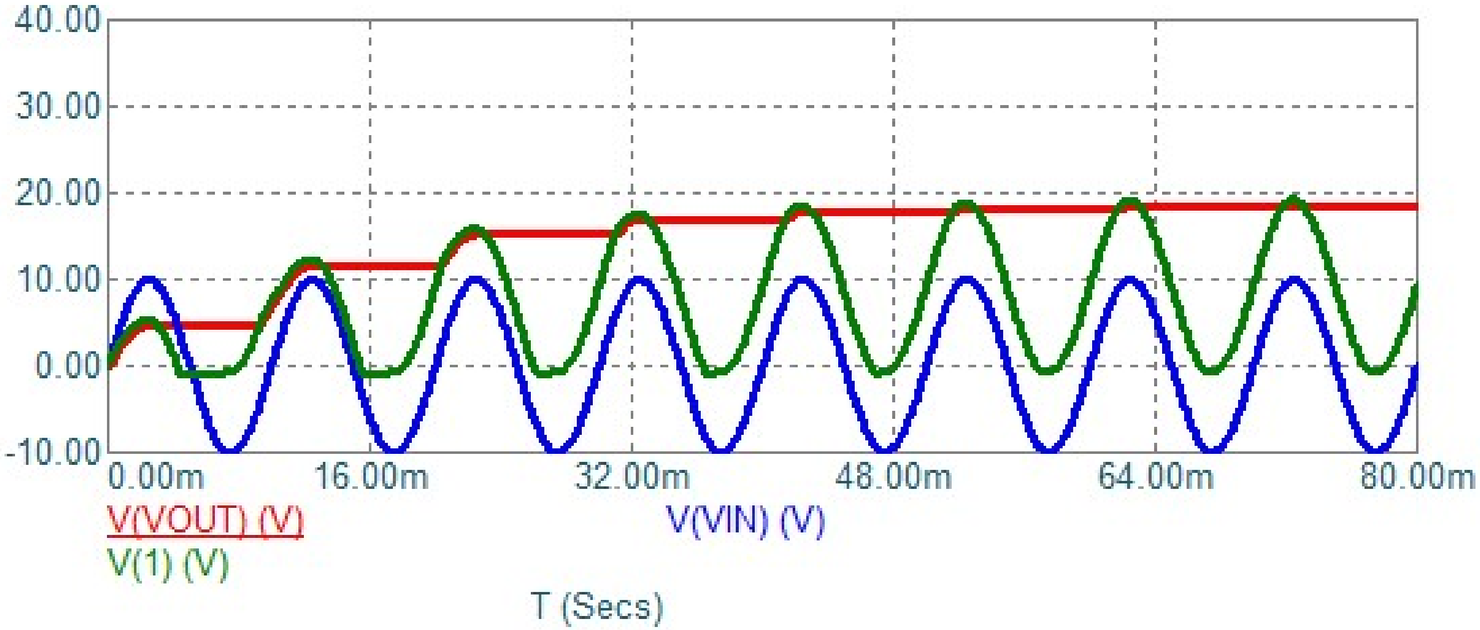
Peak Detector





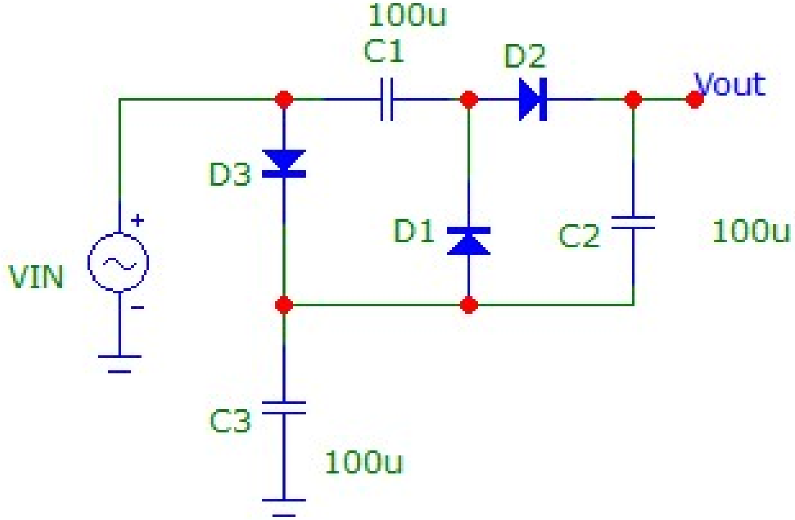
Voltage Doubler

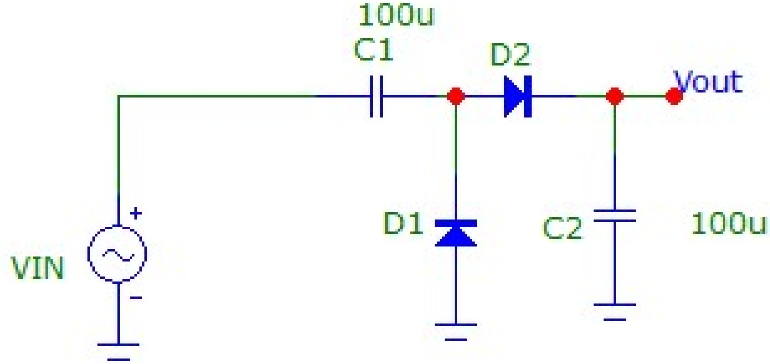


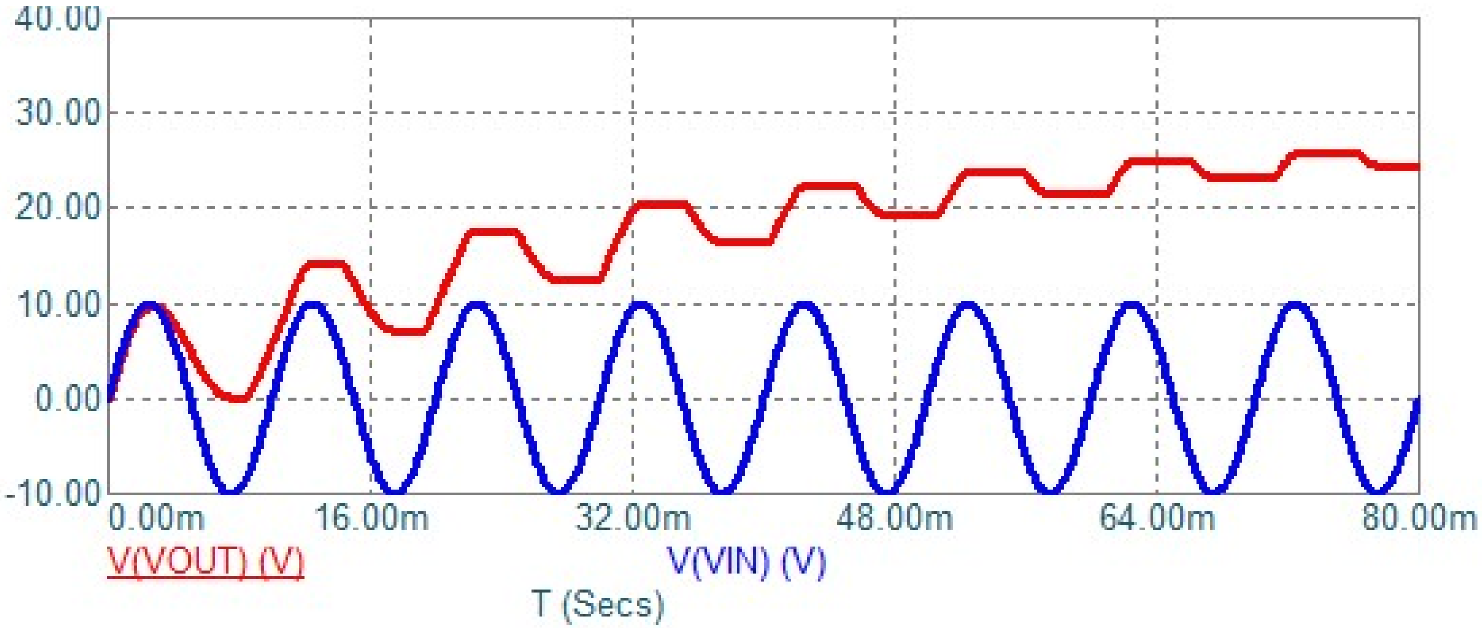


Voltage Tripler

$10V sin(\omega t)$







Temperature dependence of diode characteristics

$$I_D = I_S \times \{\exp(\frac{V_d}{V_T}) - 1\}$$

$$V_T = \frac{kT}{Q}$$

$$I_S \propto n_i^2 \propto e^{-\frac{E_g}{kT}}$$

Reverse saturation current increases with temperature. For forward bias, even though V_T increases, current still increases because of greater influence of I_S

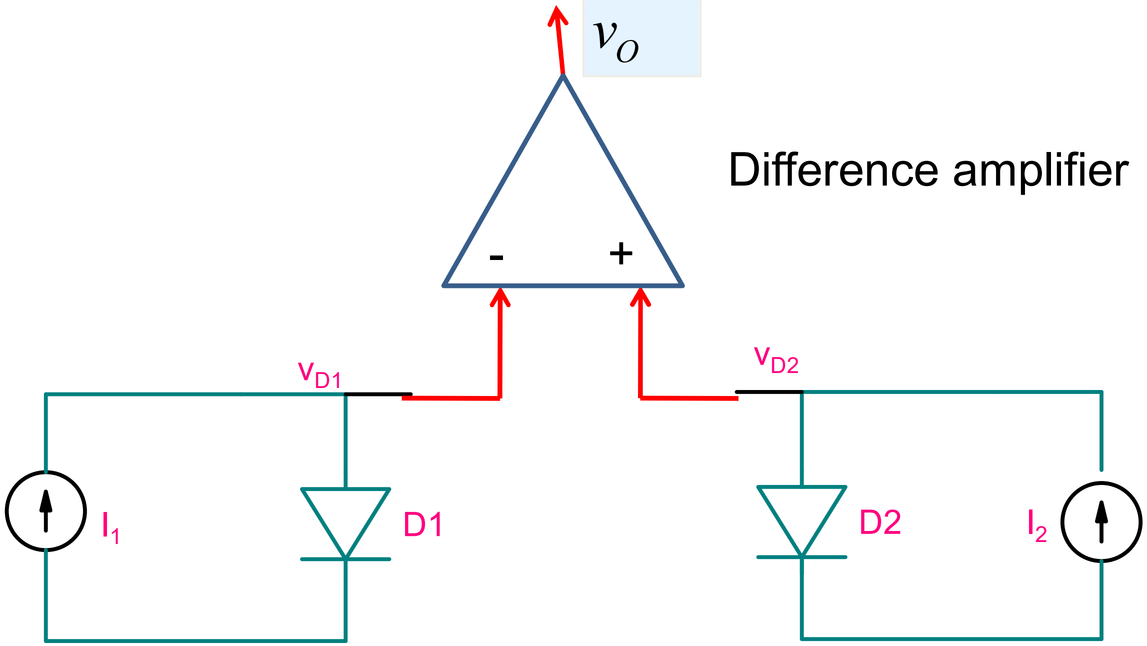
For a diode in forward bias at a fixed current I_O : $v_D = V_T \times \ln(I_O / I_S + 1)$

For Silicon diodes, v_D decreases at the rate of ~ -2mV/^{o}C

If the diode voltage is 0.7 at 27^{o}C, then at 100^{o}C it would be only :

$$0.7 - 2 \times 10^{-3} \times (100 - 27) = 0.554V$$

Measurement of temperature using a pn junction diode



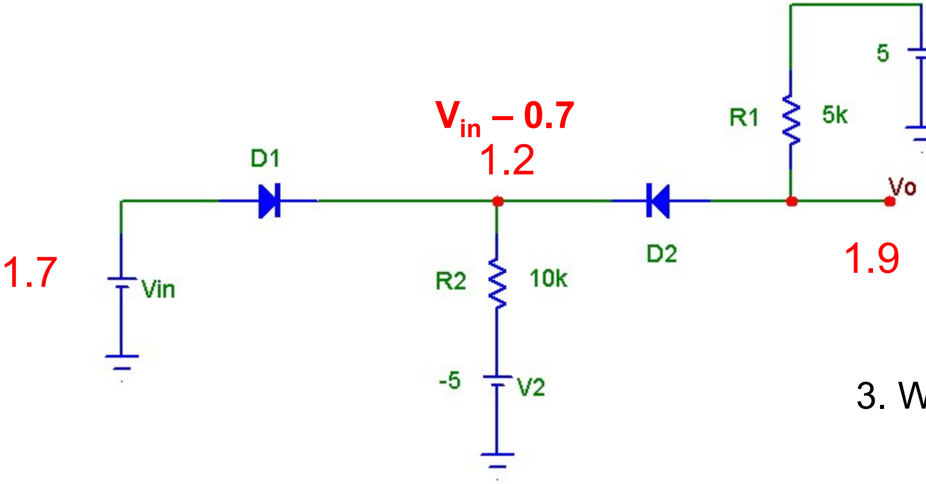
$$v_{D1} = V_T \times \ln(I_1/I_S + 1)$$

$$v_{D2} = V_T \times \ln(I_2/I_S + 1)$$

$$v_O = C \times (v_{D2} - v_{D1})$$

$$v_O = (C \times \frac{k}{q} \times \ln(\frac{I_2}{I_1})) \times T$$

Multiple-diode Circuits



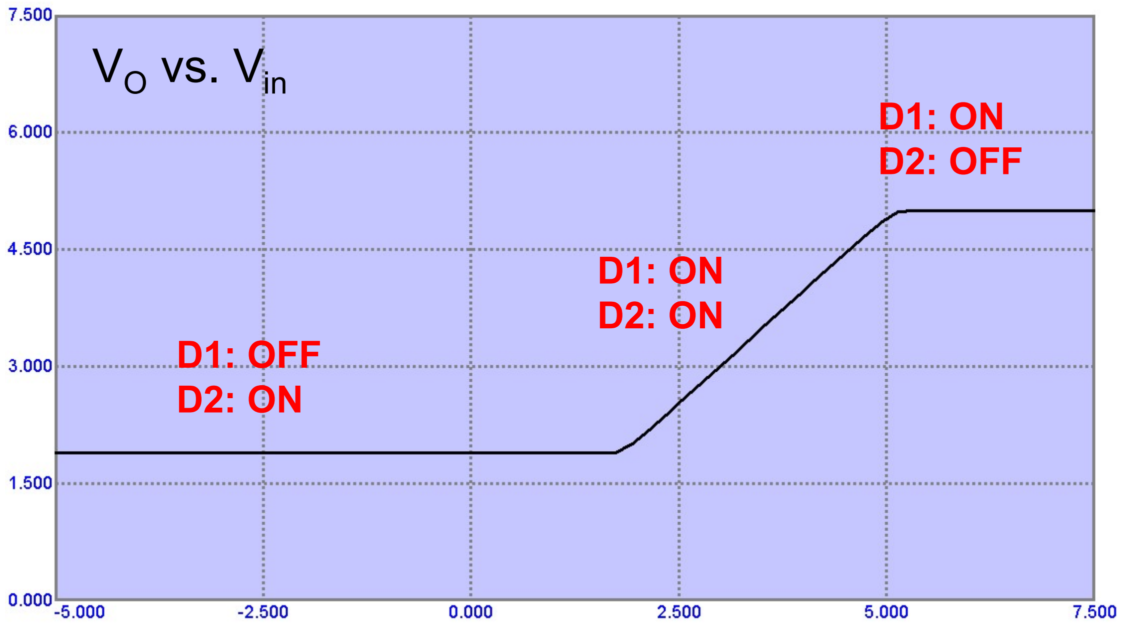
1. D1 is OFF and D2 is ON

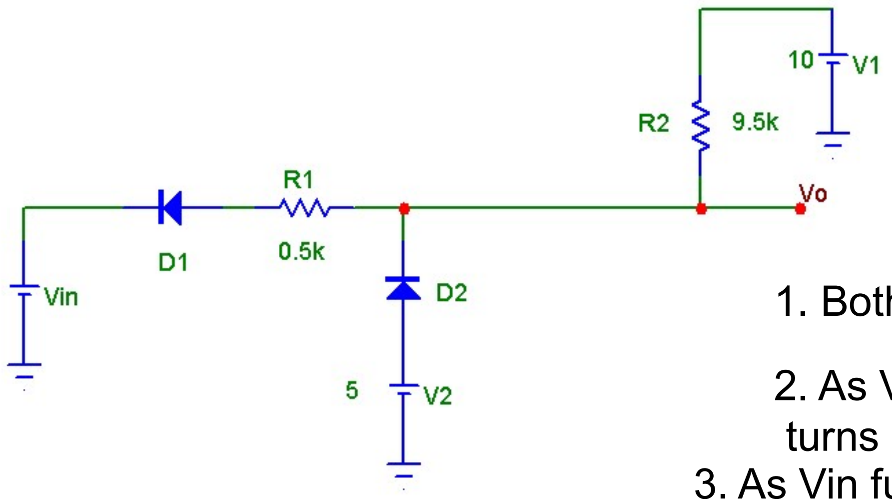
$V_o = V_{in} - 0.7 + 0.7 = V_{in}$

2. When Vin reaches 1.7, D1 also turns ON

3. When Vo reaches 5V, D2 turns OFF

V_o = 5V constant

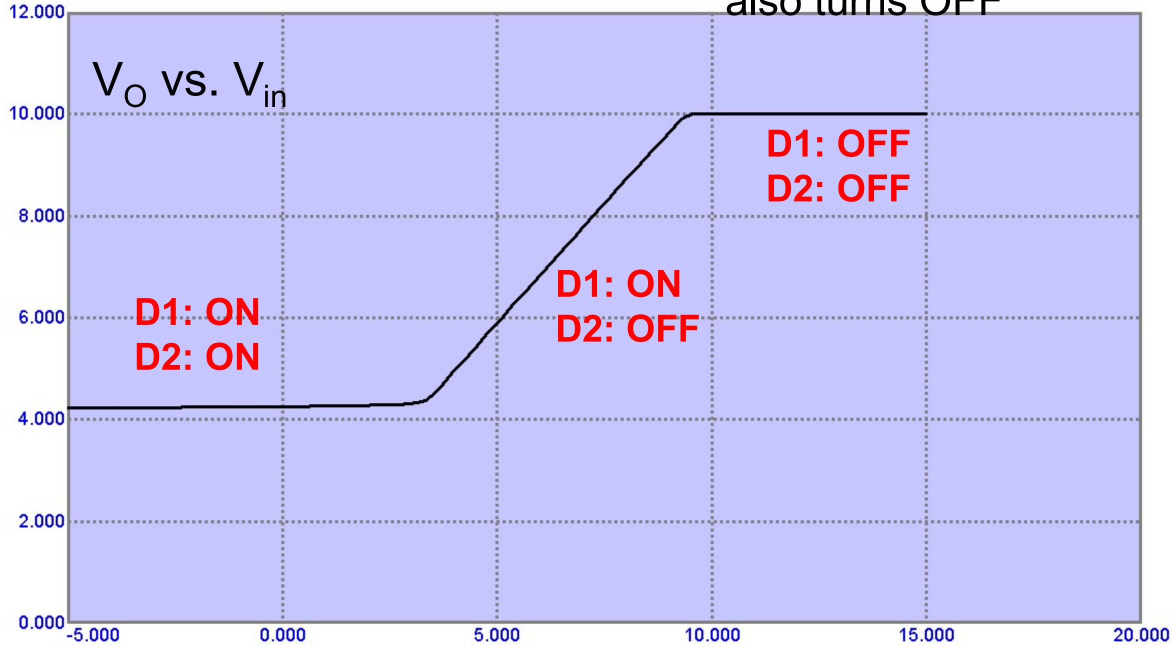




1. Both diodes are initially ON

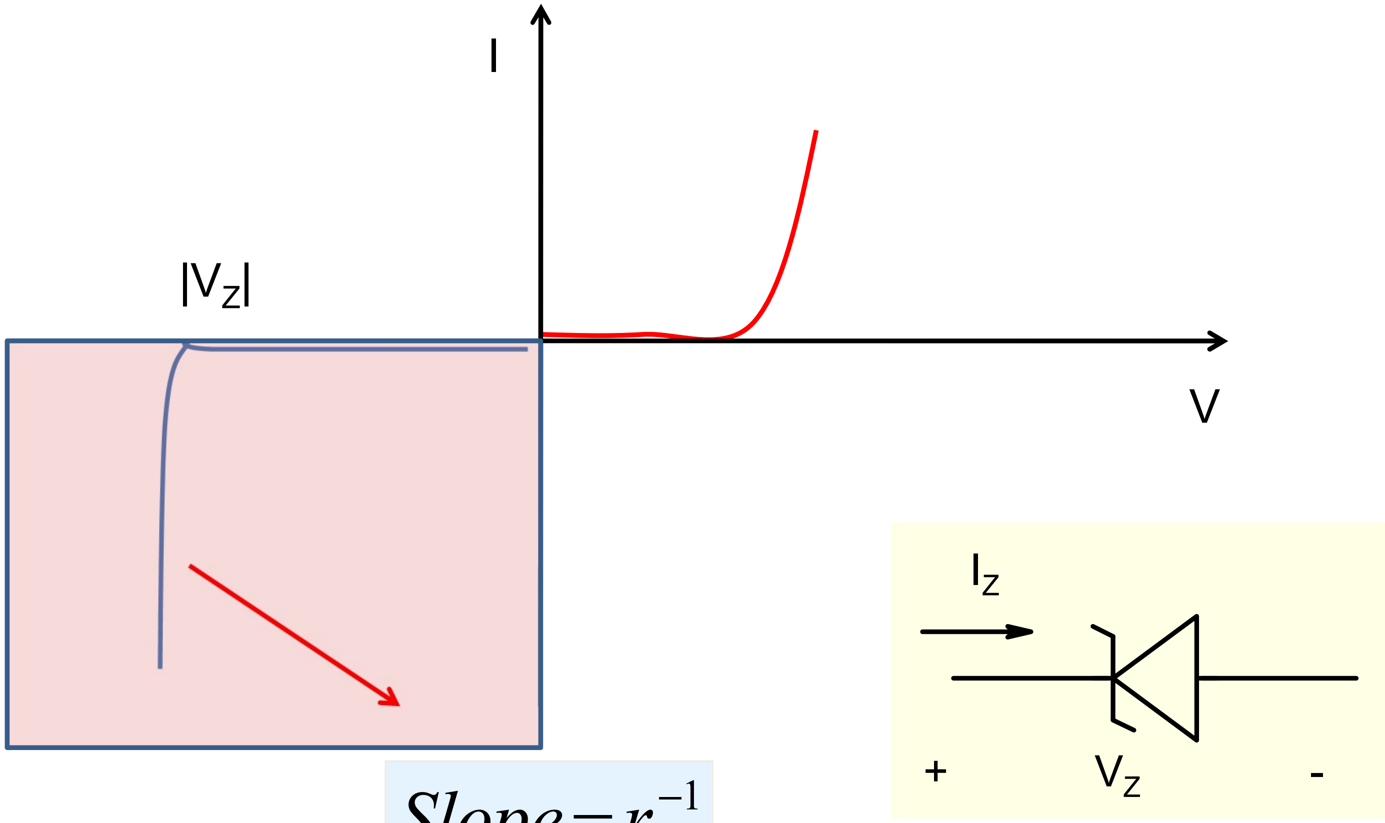
2. As Vin increases, eventually D2 turns OFF

3. As Vin further increases, eventually D1 also turns OFF



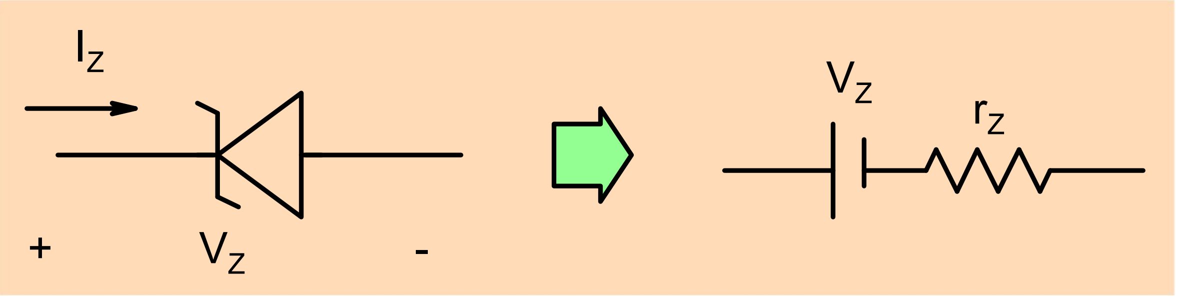
Zener Diode

A diode specially designed to operate in reverse bias in ‘breakdown’ region



$$Slope = r_Z^{-1}$$

Model



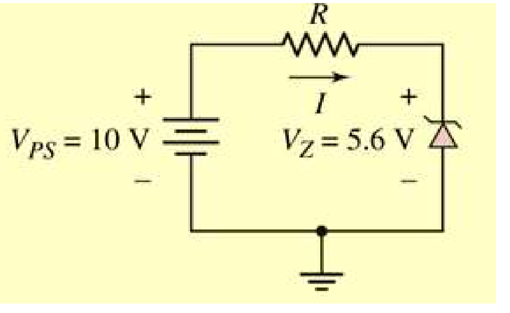
Often we will assume that r_z is negligible

Example

Given $V_Z = 5.6V$

$r_Z = 0\Omega$

Find a value for R such that the current through the diode is limited to 3mA



$$I = \frac{V_{PS} - V_Z}{R}$$

$$R = \frac{V_{PS} - V_Z}{I} = \frac{10V - 5.6V}{3mA} = 1.47k\Omega$$

$$P_Z = I_Z V_Z = 3mA \cdot 5.6V = 1.68mW$$

Datasheet

Zeners
1N4728A - 1N4752A

Absolute Maximum Ratings*

T_A = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
P_D	Power Dissipation Derate above 50°C	1.0 6.67	W mW/°C
T_{STG}	Storage Temperature Range	-65 to +200	°C
T_J	Operating Junction Temperature	+ 200	°C
$R_{\theta JL}$	Thermal resistance Junction to Lead	53.5	°C/W
$R_{\theta JA}$	Thermal resistance Junction to Ambient	100	°C/W
	Lead Temperature (1/16" from case for 10 seconds)	+ 230	°C
	Surge Power**	10	W

*These ratings are limiting values above which the serviceability of the diode may be impaired.
**Non-recurrent square wave PW = 8.3 ms, TA = 55 degrees C.

NOTES:
1) These ratings are based on a maximum junction temperature of 200 degrees C.
2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Tolerance: A = 5%

DO-41

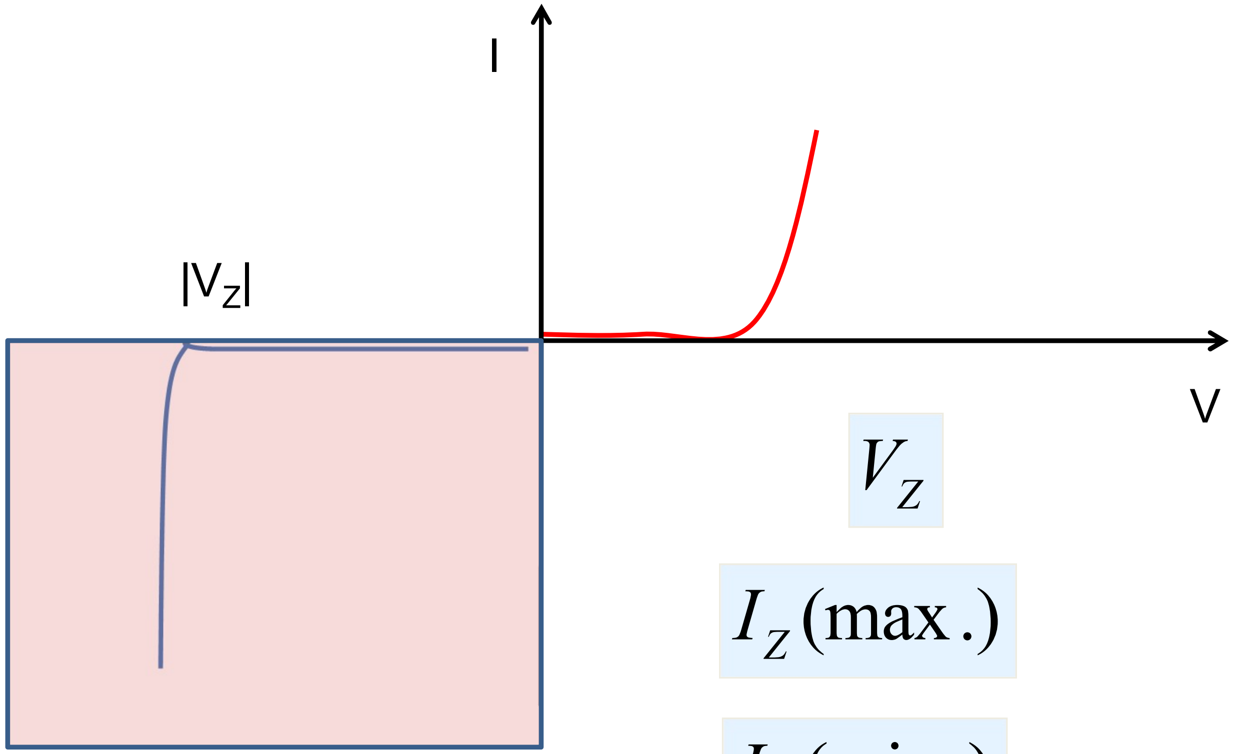
COLOR BAND DENOTES CATHODE

Electrical Characteristics

T_A = 25°C unless otherwise noted

Device	V_Z (V)	Z_Z (Ω) @	I_{ZT} (mA)	Z_{ZK} (Ω) @	I_{ZK} (mA)	V_R (V) @	I_R (μA)	I_{SURGE} (mA)	I_{ZM} (mA)
1N4728A	3.3	10	76	400	1.0	1.0	100	1380	276
1N4729A	3.6	10	69	400	1.0	1.0	100	1260	252
1N4730A	3.9	9.0	64	400	1.0	1.0	50	1190	234
1N4731A	4.3	9.0	58	400	1.0	1.0	10	1070	217
1N4732A	4.7	8.0	53	500	1.0	1.0	10	970	193
1N4733A	5.1	7.0	49	550	1.0	1.0	10	890	178
1N4734A	5.6	5.0	45	600	1.0	2.0	10	810	162
1N4735A	6.2	2.0	41	700	1.0	3.0	10	730	146
1N4736A	6.8	3.5	37	700	1.0	4.0	10	660	133
1N4737A	7.5	4.0	34	700	0.5	5.0	10	605	121
1N4738A	8.2	4.5	31	700	0.5	6.0	10	550	110
1N4739A	9.1	5.0	28	700	0.5	7.0	10	500	100
1N4740A	10	7.0	25	700	0.25	7.6	10	454	91
1N4741A	11	8.0	23	700	0.25	8.4	5.0	414	83
1N4742A	12	9.0	21	700	0.25	9.1	5.0	380	76
1N4743A	13	10	19	700	0.25	9.9	5.0	344	69
1N4744A	15	14	17	700	0.25	11.4	5.0	304	61
1N4745A	16	16	15.5	700	0.25	12.2	5.0	285	57
1N4746A	18	20	14	750	0.25	13.7	5.0	250	50
1N4747A	20	22	12.5	750	0.25	15.2	5.0	225	45
1N4748A	22	23	11.5	750	0.25	16.7	5.0	205	41
1N4749A	24	25	10.5	750	0.25	18.2	5.0	190	38
1N4750A	27	35	9.5	750	0.25	20.6	5.0	170	34
1N4751A	30	40	8.5	1000	0.25	22.8	5.0	150	30

Zener diode: Important Characteristics

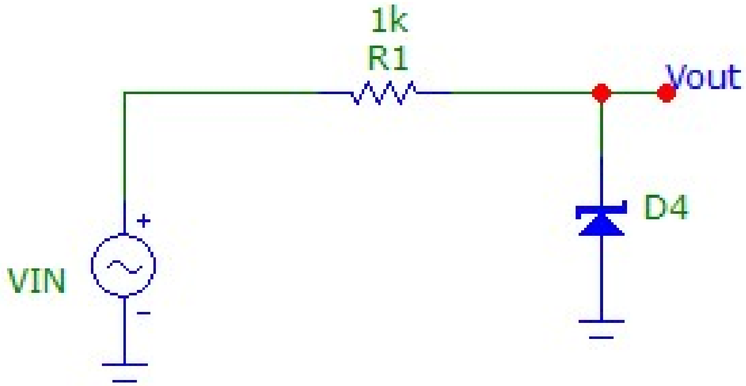


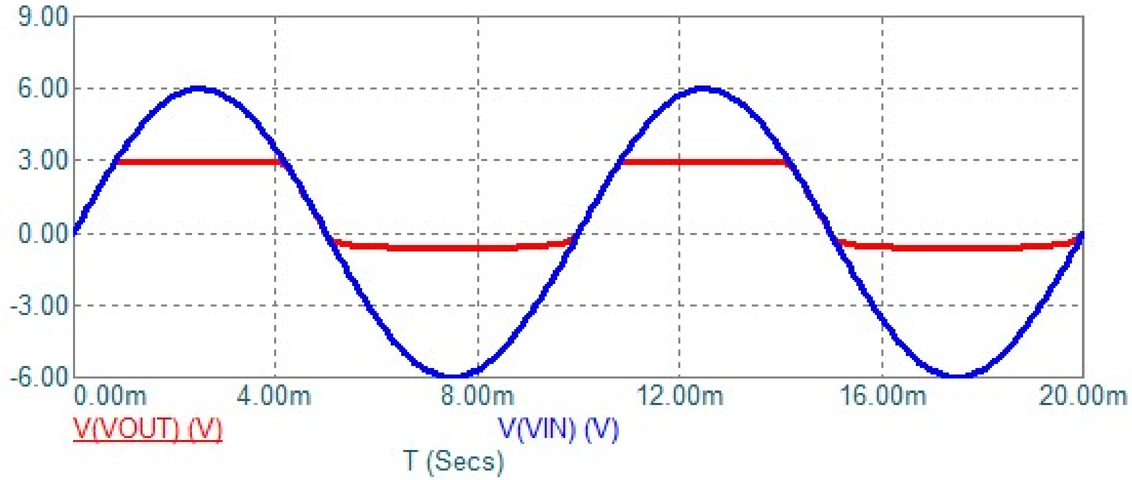
V_Z

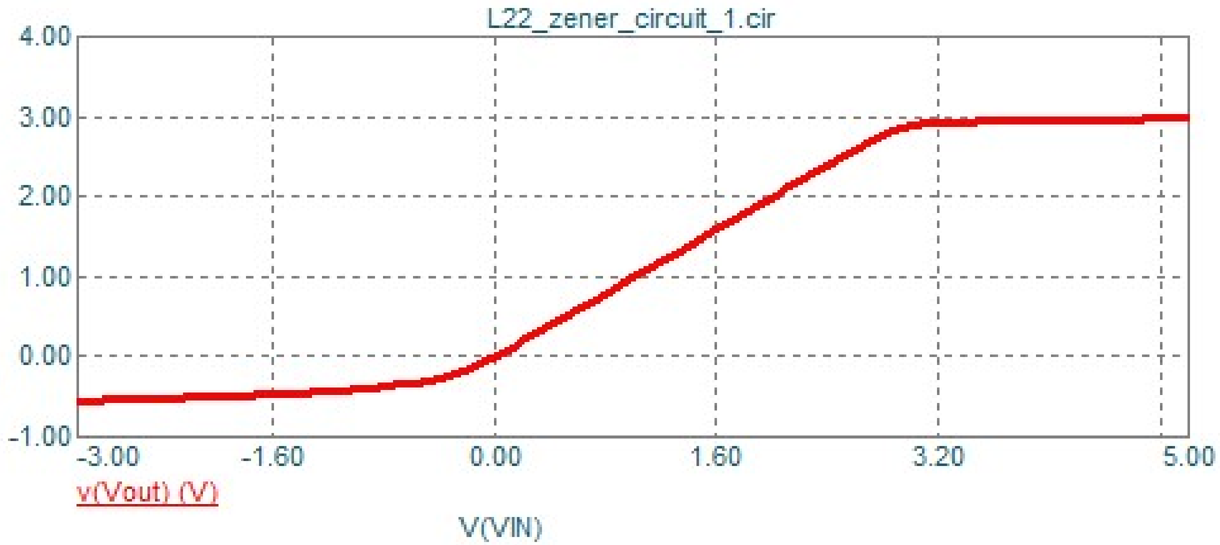
$I_Z(\max.)$

$I_Z(\min.)$

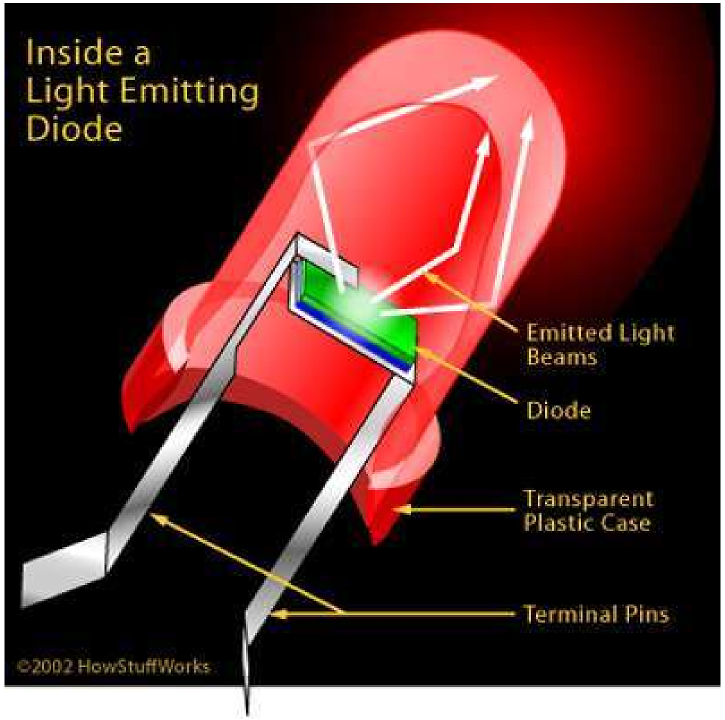
P_Z


1k
R1
Vout
D4
VIN

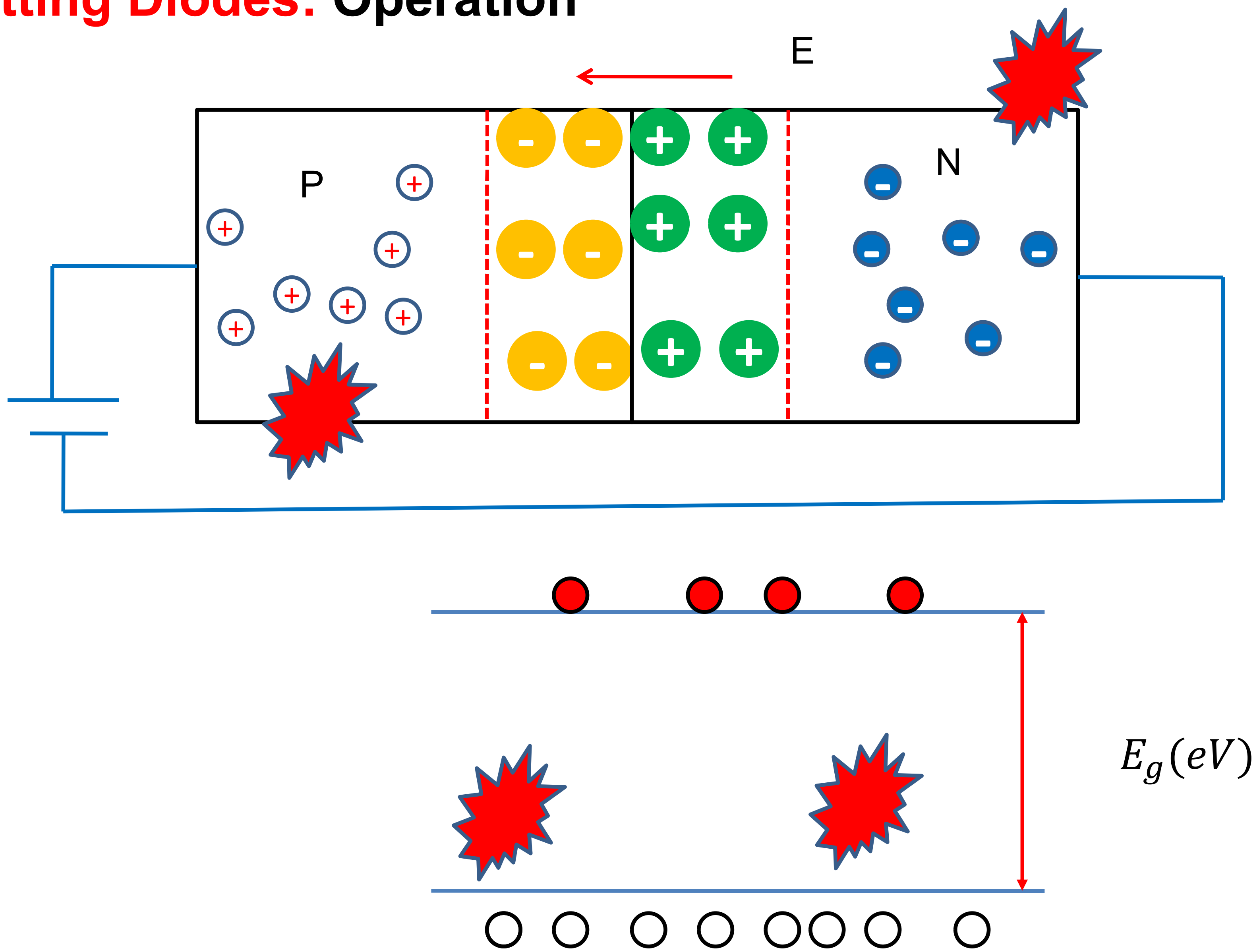

9.00
6.00
3.00
0.00
-3.00
-6.00
0.00m
4.00m
8.00m
12.00m
16.00m
20.00m
V(VOUT) (V)
V(VIN) (V)
T (Secs)


L22_zener_circuit_1.cir
4.00
3.00
2.00
1.00
0.00
-1.00
-3.00
-1.60
0.00
1.60
3.20
5.00
v(Vout) (V)
V(VIN)

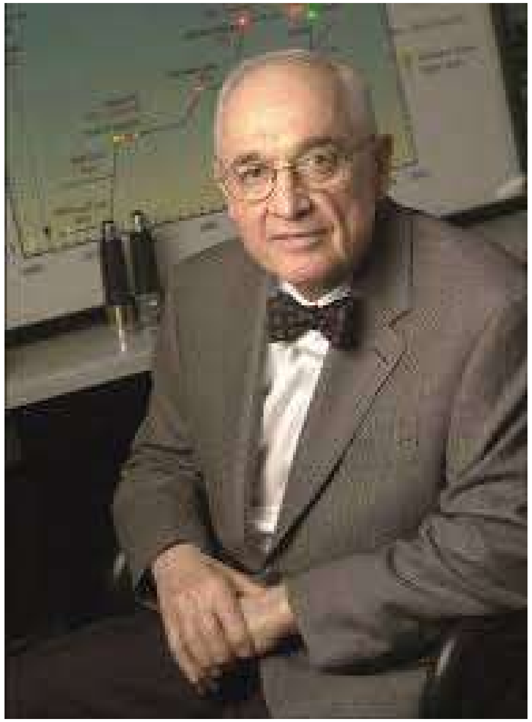
Light Emitting Diodes



Light Emitting Diodes: Operation



Invention of LED

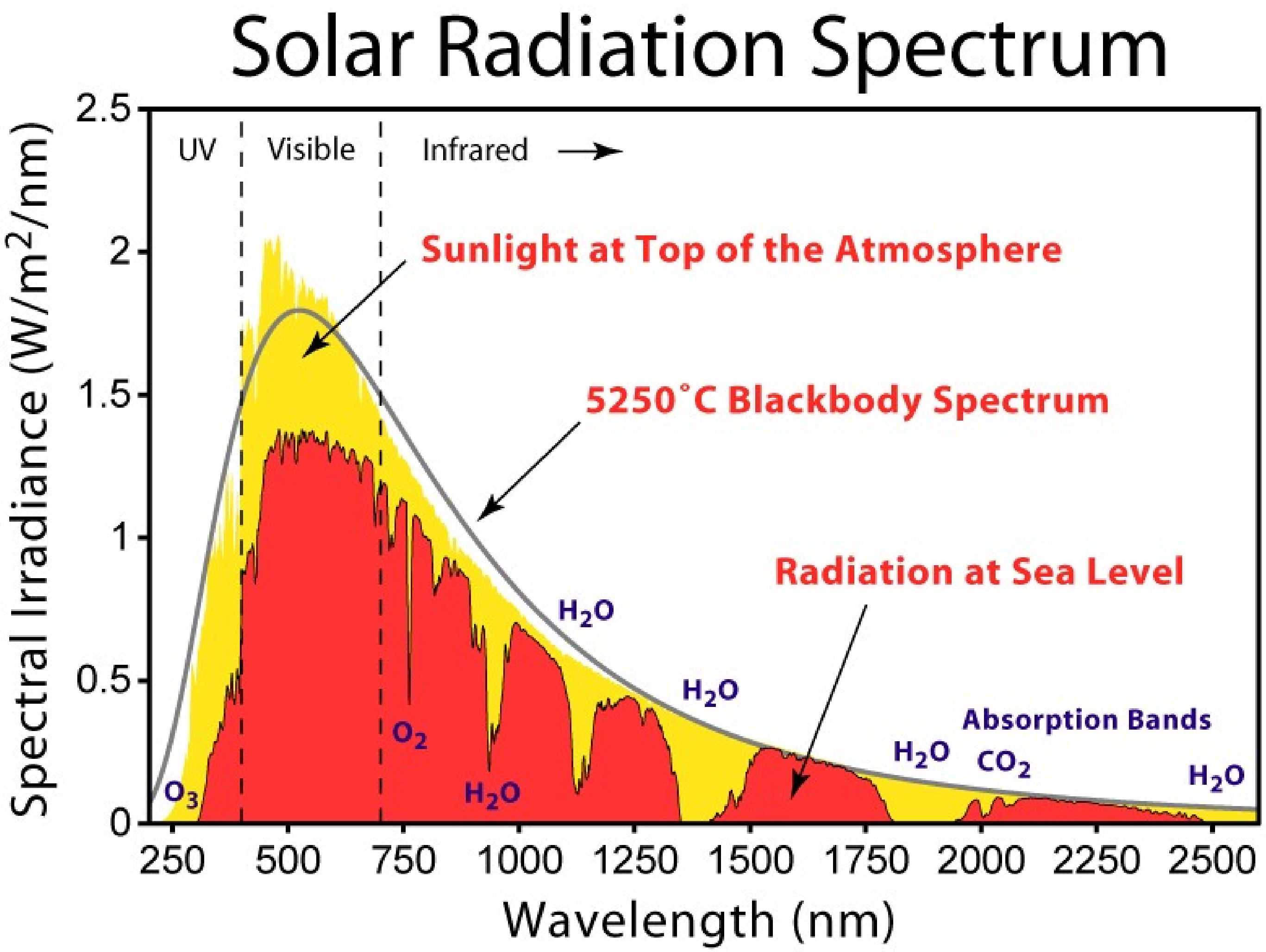


Nick Holonyak
1962; Red LED using GaAsP

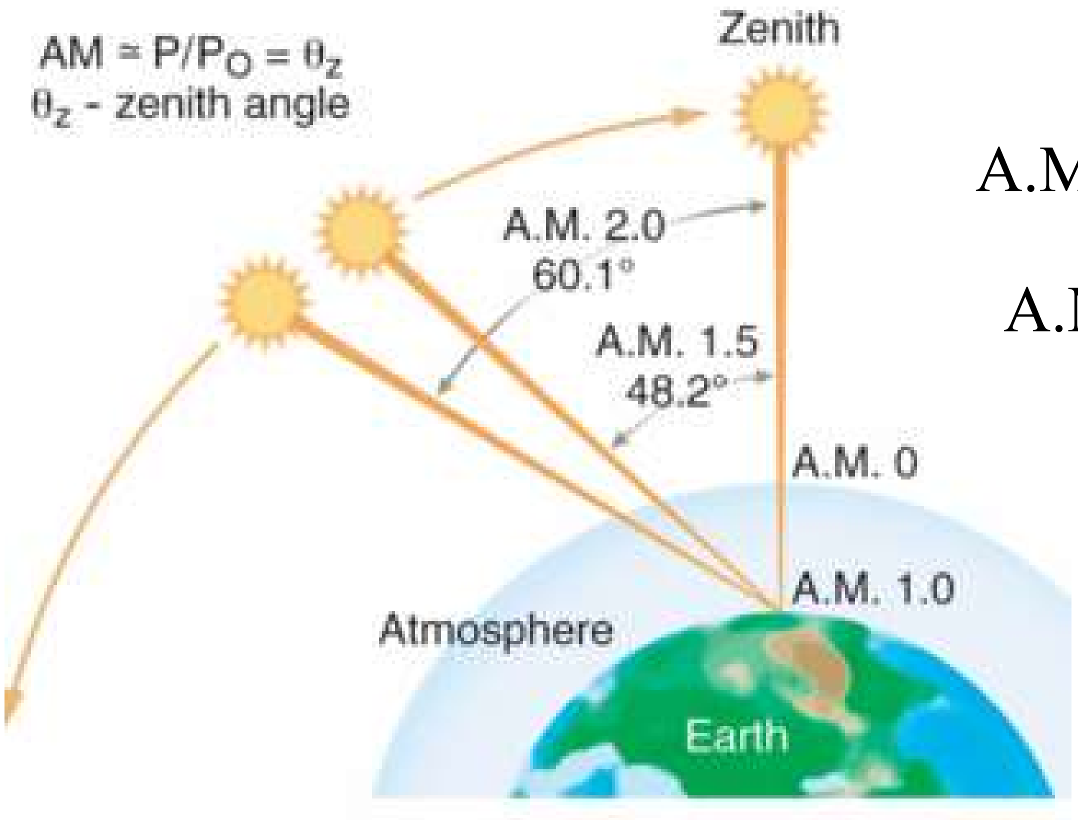
Shuji Nakamura
Blue LED using GaN, 1992
Nobel Prize, 2014

PN Junction as a Solar Cell

Sun as a source of energy



Sun as a source of energy



A.M.0 ~1367 W/m^2

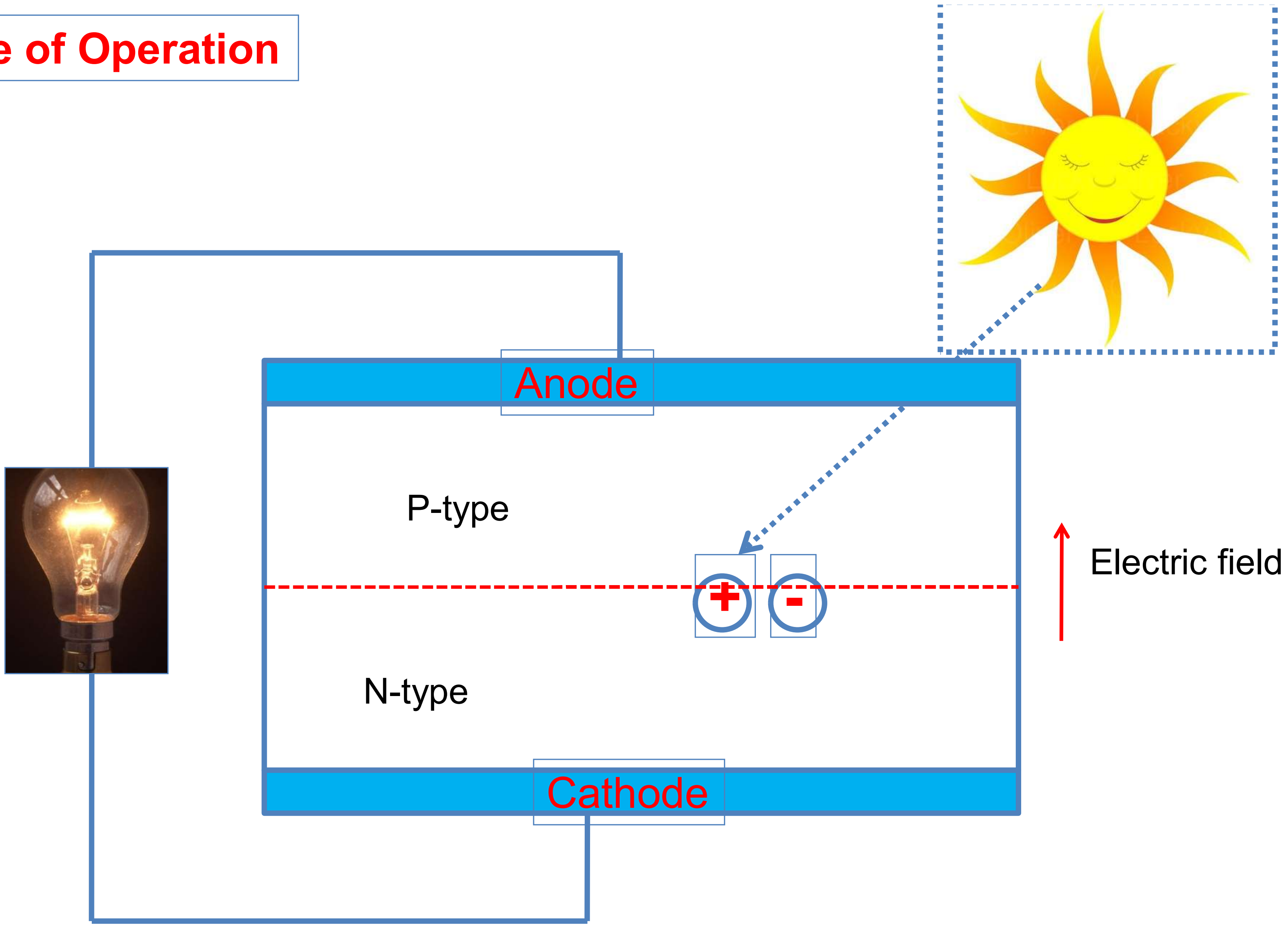
A.M.1 ~925 W/m^2

A.M.1.5 ~844 W/m^2

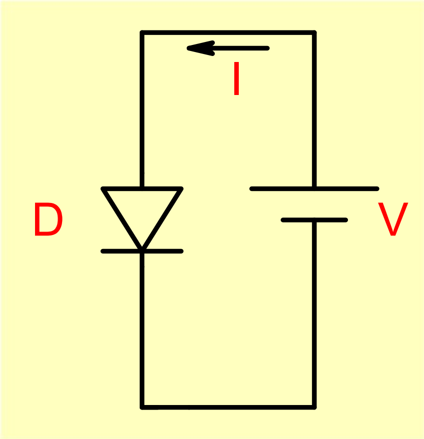
A.M.2 ~691 W/m^2

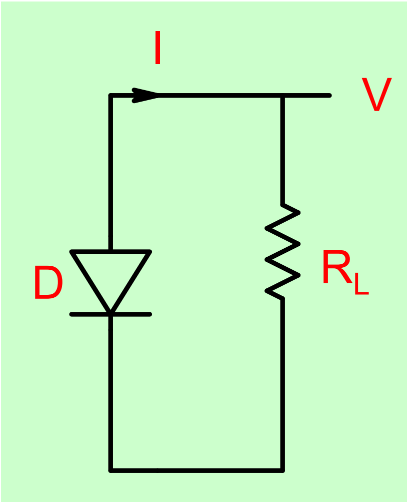
AM: air mass

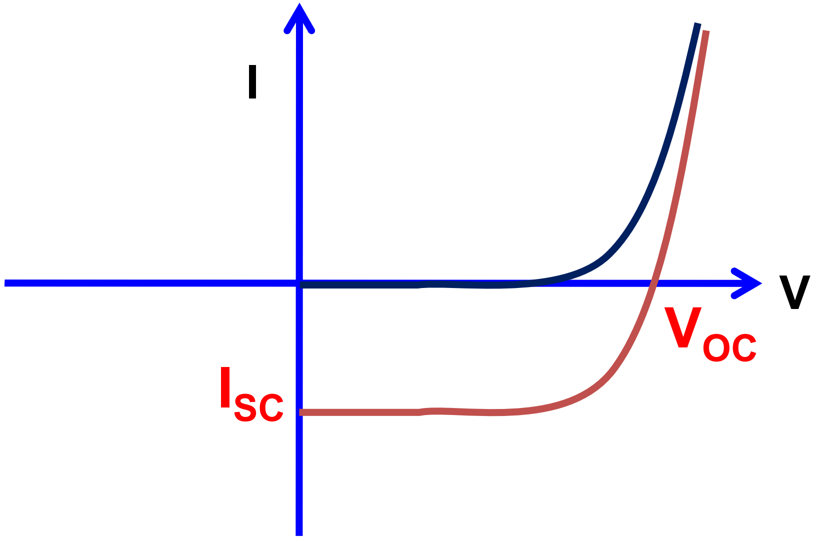
Principle of Operation



Solar cell is a diode

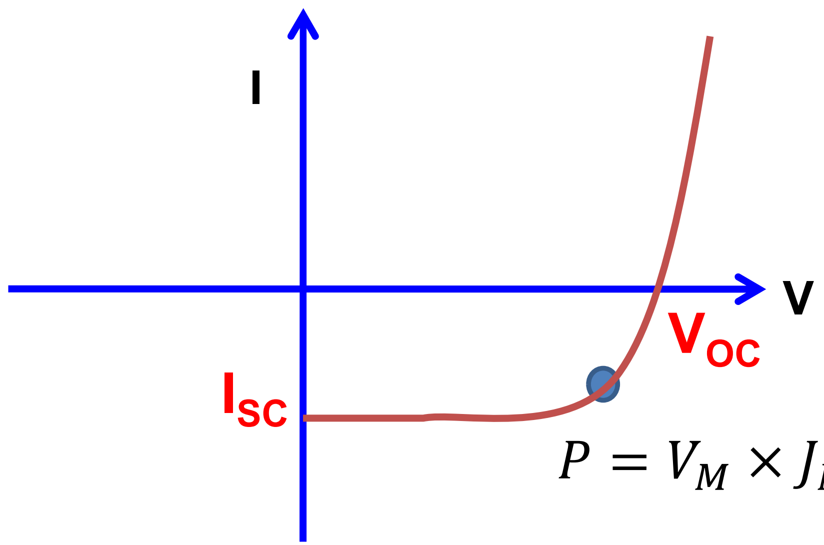






V_{OC} : Open circuit voltage
I_{SC} : Short circuit current

What is the maximum power that can be extracted?



$$P = V_M \times J_M$$

$$P = \frac{V_M \times J_M}{V_{OC} \times J_{SC}} \times V_{OC} \times J_{SC}$$

$$P = FF \times V_{OC} \times J_{SC}$$

Parameters of the Ideal Silicon Cell and the Best
PERL Cell, and Achievable Parameters of a PERL Cell (AM1.5)

	Jsc (mA/cm2)	Voc (mV)	FF (%)	Eff. (%)
ideal cell[15]	43.0	769	89.0	29
best PERL[18]	40.8	708	83.1	24
achievable cell[19]	42.5	730	84.0	>26

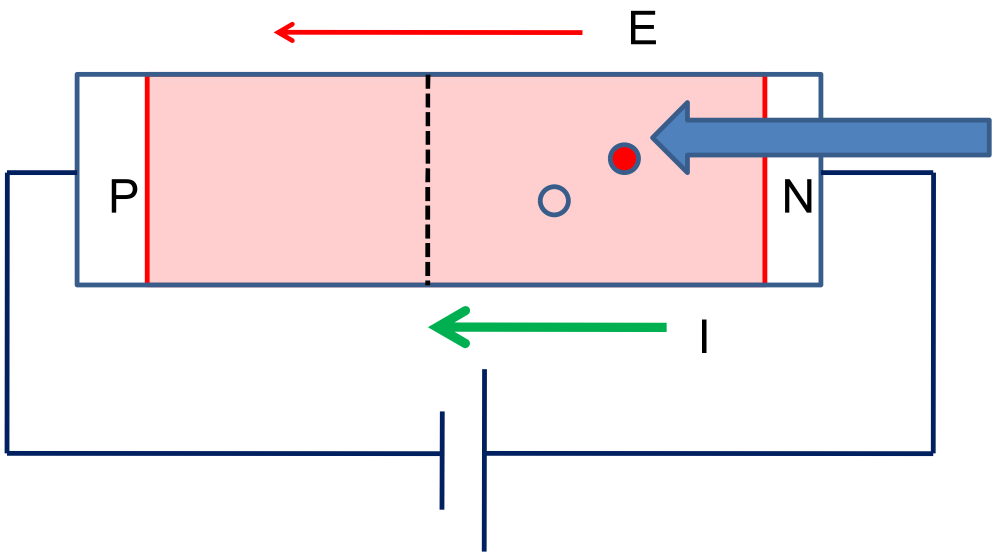
$$P_{ext} = J_{SC} \times V_{OC} \times FF = 43 \times 0.769 \times 0.89 = 29.4mW\ for\ 100mW\ of\ incident\ solar\ power\ (1\ sun)$$

CITY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG.
AGRA	3.58	4.65	5.53	5.96	6.33	5.98	4.94	4.51	4.68	4.69	3.91	3.42	4.85
ALLAHABAD	3.79	4.83	5.93	6.39	6.55	5.68	4.56	4.31	4.48	4.8	4.23	3.6	4.93
GORAKHPUR	3.41	4.25	5.28	5.88	6.5	6.34	5.66	5.35	5.02	4.54	3.74	3.2	4.93
KANPUR	3.62	4.63	5.68	6.19	6.54	5.88	4.78	4.45	4.45	4.83	4.14	3.52	4.89
LUCKNOW	3.62	4.63	5.68	6.19	6.54	5.88	4.78	4.45	4.45	4.83	4.14	3.52	4.89
MEERUT	3.6	4.53	5.73	6.7	7.28	6.68	5.54	4.9	5.17	5.01	4.15	3.47	5.23

$kWh\ /\ m^2/\mathrm{day}$

$18\%\ efficient\ solar\ panel\ of\ 1\mathrm{m}^2\ would\ generate\ 0.9kWh$

PN Junction as a Photodiode or detector



A specially designed Reverse-biased PN junction is used to detect light.